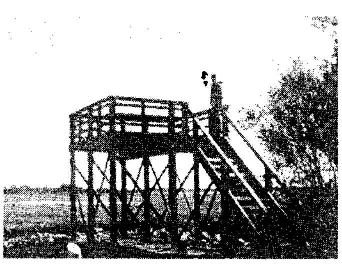
US Army Corps of Engineers



ENVIRONMENTAL IMPACT
RESEARCH PROGRAM

TECHNICAL REPORT EL-95-27

FIXED AREA PLOT SAMPLING FOR FOREST INVENTORY

Section 6.2.4, U.S. ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL

by

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September 1995

Final Report

Prepared for DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under EIRP Work Unit 32420

PREFACE

This work was sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Environmental Impact Research Program (EIRP), Work Unit 32420, entitled Development of U.S. Army Corps of Engineers Wildlife Resources Management Manual. Mr. Dave Mathis, CERD-C, was the EIRP Coordinator at the Directorate of Research and Development, HQUSACE. The Program Monitors for the study were Dr. John Bushman, Mr. F. B. Juhle, and Mr. Forrester Einarsen, HQUSACE.

This report was prepared by Dr. Wilma A. Mitchell, Stewardship Branch (SB), Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), and Dr. H. Glenn Hughes, School of Forest Resources, Pennsylvania State University (DuBois Campus), DuBois, PA. Dr. Hughes was assigned to EL under an Intergovernmental Personnel Act agreement during the development of this report. Mr. Chester O. Martin, SB, was principal investigator for the work unit. WES review was provided by Mr. Martin, Mr. Michael R. Waring, and Mr. Darrell Evans, SB.

The report was prepared under the general supervision of Mr. Hollis Allen, Acting Chief, SB, EL; Dr. Robert M. Engler, Chief, Natural Resources Division, EL; and Dr. John W. Keeley, Director, EL. Dr. Russell F. Theriot, WES, was the EIRP Program Manager.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.

This report should be cited as follows:

Mitchell, Wilma A., and Hughes, Glenn, H. 1995. "Fixed Area Plot Sampling for Forest Inventory: Section 6.2.4, U.S. Army Corps of Engineers Wildlife Resources Management Manual," Technical Report EL-95-27, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

NOTE TO READER

This report is designated as Section 6.2.4 in Chapter 6 -- CENSUS AND SAMPLING TECHNIQUES, Part 6.2 -- VEGETATION SAMPLING TECHNIQUES, of the U.S. ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL. Each section of the manual is published as a separate Technical Report but is designed for use as a unit of the manual. For best retrieval, this report should be filed according to section number within Chapter 6.

FIXED AREA PLOT SAMPLING FOR FOREST INVENTORY

Section 6.2.4, U.S. ARMY CORPS OF ENGINEERS

WILDLIFE RESOURCES MANAGEMENT MANUAL

Fixed area plots (quadrats) can be used to determine forest stand parameters useful in wildlife habitat analysis and resource management. The quadrat method was introduced into ecological studies around 1900 (Haig 1929). A variety of frames have been constructed to delineate small plots for sampling cover or plant frequency (Ellison 1942, Daubenmire 1959, Blair 1963, Hyder et al. 1965, Segura 1969, Morris 1973, Bonham 1976, Baker and Pearson 1981, Anderson and Kothmann 1982, Neal et al. 1988). The plots used for stand characterization and wildlife habitat evaluation are large quadrats outlined by invisible boundaries that are established by pacing from the plot center outward.

TECHNIQUE SELECTION

The fixed area plot technique is highly appropriate for the evaluation of forest vegetation associated with wildlife habitat. The procedure described in this report emphasizes basal area, density, and average tree diameter, which are major parameters sought in vegetation analyses. A first-time survey may be used to collect data for a specific study or to establish a baseline for future reference. The establishment of permanent plots allows for subsequent surveys to determine changes within a stand over time.

Plot sampling requires fewer sampling units than prism sampling for an adequate sample size (Burkhardt et al. 1984). However, plot methods may not be as efficient because more time is usually required per sample unit than for prism sampling. Plot sampling is more precise than prism sampling in square lattice stands but is less precise in clumped and random stands (Oderwald 1981).

Equipment is inexpensive, and data can be collected by one individual if necessary. Personnel requirements usually depend upon the intensity of sampling. Species composition and diameter measurements can be readily collected by 1 person, but data collection is more efficient when performed by at least 2 crew members.

STUDY DESIGN

Site Selection

Aerial photographs should be studied and a ground reconnaissance should be conducted to determine the size and characteristics (e.g., terrain, forest heterogeneity) of the study area. The sites to be sampled should be selected and located on a map of the study area prior to data collection. If the area is large with fairly homogeneous forest stands, sites should be randomly selected. However, if the study area consists of diverse forest types (e.g., hardwood, coniferous, and mixed), it may be preferable to select sites representative of these types in proportion to the amount of area occupied by each.

Sampling Design

Plot location. Completely random sampling, in which sample plots are located independently of one another, minimizes bias and satisfies statistical assumptions. However, random sampling is more difficult and time consuming than other sampling designs. Systematic (grid) sampling is probably the easiest design; plots are located at predetermined intervals along transects evenly spaced throughout the stand, but these plots are not randomly located for purposes of statistical analysis. As a compromise, a design consisting of a combination of random and systematic sampling may be used to locate plots. In this design, plots are randomly spaced along fixed lines, or fixed plots are located on randomly spaced lines. It can then be assumed that the trees sampled represent overall stand conditions.

There is no standard spacing for plots on a transect. However, plots should be located far enough apart to prevent sampling overlap and yet adequately cover the entire study area. The method for determining an adequate sample size is presented below.

<u>Plot size</u>. There is no standard plot size for sampling a forest stand. However, a 0.1-acre circular plot is frequently used because it is a convenient size to sample and data are easy to analyze with the plot size in decimal units. The data used for examples in this report were collected in 0.1-acre circular plots.

<u>Sampling procedure</u>. Species and stem diameter are the only 2 variables for which data are collected in the method described herein. The minimum diameter for sample trees will be determined by the objectives of the study; 5 in. is the minimum used in most vegetation studies.

Each sample tree is identified to species, and its diameter is measured. Basal area, density, and average tree diameter can be calculated from these variables. Timber volume can also be determined, but it is of limited value in wildlife habitat analysis.

A standard method for sampling borderline trees should be established and used throughout the study to help eliminate bias and reduce error in the final results. A common practice is to measure every other borderline tree.

<u>Sample size</u>. The number of sample plots should be based on the approximate acreage of the study area with consideration given to representative forest types within the area. Sample size can be calculated if data are separated by plots. A formula commonly used to calculate sample size (Snedecor 1950) is

$$N = \frac{s^2 t^2}{d^2}$$

where

N = number of sample points needed

s = standard deviation

t = t-value with n-1 degrees of freedom

d = allowable error (i.e., arithmetic mean of the sample total times the designated percent accuracy)

After data collection has begun, these formulas may be used to determine the number of samples needed for adequate sampling. If different forest types are inventoried, sample size should be determined for each representative type.

EQUIPMENT

A diameter tape and Biltmore stick are used to measure tree diameters. A 20-ft tape (76-in. diameter) with claw hook is recommended; one with black graduations on white enameled steel line is easiest to read. The Biltmore stick should be calibrated for a 25-in. (64-cm) reach and be capable of measuring diameters up to 74 in.

Other items of equipment needed are a marker to identify plot center and a linear tape to determine pace length. Stake wire flags are recommended for plot center markers, because they are lightweight and easy to transport. Pace length can be measured with a general utility tape, surveyor's rope, or reel tape.

These items can be purchased from forestry retailers. The approximate costs are $50.00 for a diameter tape with leather case; $35.00 for a Biltmore stick; $20.00 for a closed reel tape that is graduated on one side; and $20.00 for 100 stake wire flags and flag carrier (1994 prices).

PREPARATION

Field personnel should conduct trial runs in forest types that will be sampled during the study. This allows time for the crew to gain proficiency in measuring diameters, identifying trees, and estimating diameter at breast height (dbh) categories before the initiation of data collection.

Species Identification

Valuable time can be saved if tree identification is learned prior to sampling, especially if the area encompasses a large number of species. Field personnel should learn to identify trees by the bark, twigs, growth form, and foliage. It is difficult to distinguish individual leaf shapes on tall trees in dense forests.

Measuring Plot Radius

Field personnel should be able to rapidly identify the plot boundary and accurately determine the status of trees on or near the boundary. The easiest way to locate the plot boundary is to pace a distance equal to the plot radius (i.e., the distance from plot center to the arc describing the plot circumference). A linear tape or rope the length of plot radius may be kept at plot center to check distances to borderline trees.

Each data collector should count the number of paces required to walk from plot center to the boundary. The pace length becomes longer or shorter with an increase or a decrease, respectively, in the rate of walking; therefore, the number of required paces may need to be redetermined when working in forests with extremes in understory density.

Measuring Stem Diameter

Diameter at breast height is the variable collected most frequently for trees. It is measured at 4.5 ft above ground level. The diameter tape and Biltmore stick are devices commonly used to measure dbh.

Diameter tape. To find the dbh, the diameter tape is placed around the circumference of a tree. The tape graduations, based on the relationship between the circumference and diameter of a circle, give direct readings of stem diameter, usually to the nearest 0.1 in. If a steel diameter tape is level and pulled taut, it is the most consistent method of measuring dbh (Avery 1967). The tape is wrapped around the tree trunk and secured with the claw hook if the trunk has a large diameter (Fig. 1). It is read to the nearest inch, where the first marker line on the tape overlaps the number of inches (Fig. 2).

Biltmore stick. The Biltmore stick is a straight wooden stick specially graduated for direct readings of dbh on trees with large diameters. The graduations on the stick are usually based on a fixed distance of 25 in. from the observer's eye to dbh. Because of difficulty in maintaining the proper distance from eye to tree, the Biltmore stick is considered a rather crude measuring device (Avery 1967). However, most trees are recorded in 1- or 2-in. classes, and the stick is usually adequate for these measurements. It is especially useful if vines such as poison ivy (*Toxicodendron radicans*) are present on the stem.

The Biltmore stick should be grasped near the middle, placed horizontally against the tree trunk at breast height, and held perpendicular to eye level (Fig. 3). With one eye closed, the observer aligns the stick so that its center is the appropriate distance from the eye (usually 25 in.) and the zero end of the scale coincides with the edge of the trunk. The diameter is read as the number (to the nearest inch) that aligns with the opposite side of the tree trunk (Fig. 4).

Irregular trees. It is critical that trees be measured exactly at 4.5 ft above ground (Fig. 5a). Otherwise, a high degree of error will be introduced during data collection. When diameters are measured under heavy snow cover or

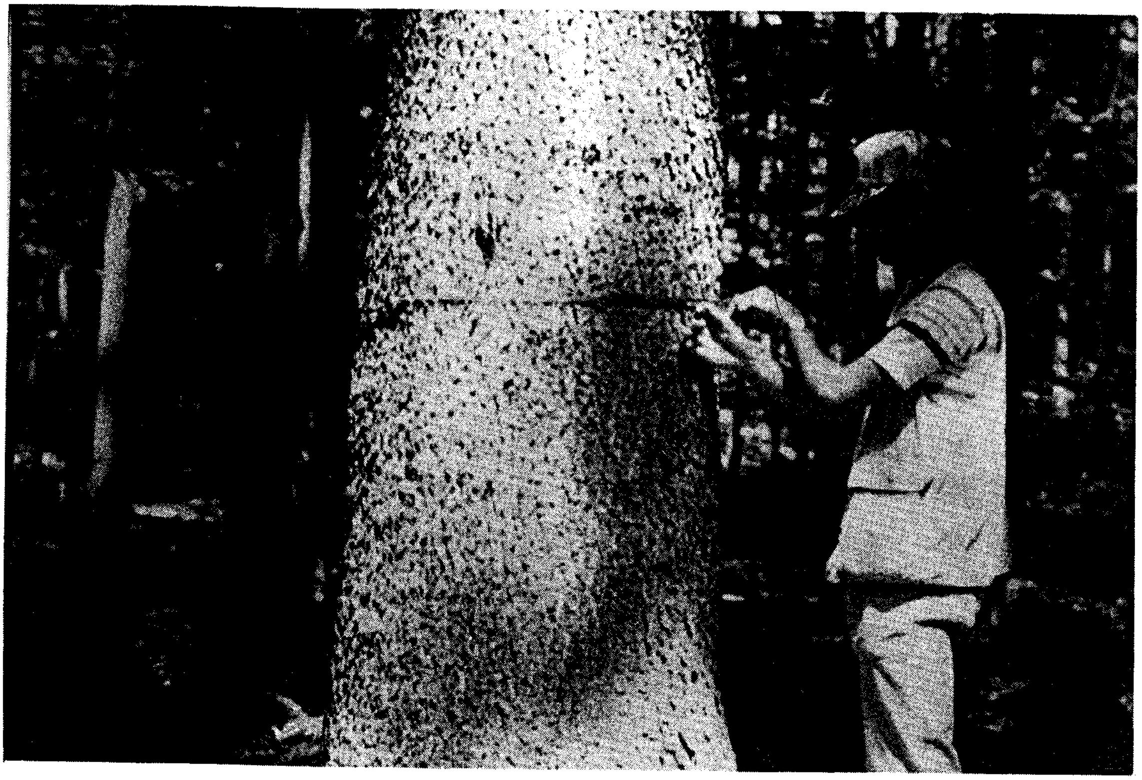

Figure 1. Using the diameter tape to measure the dbh of a tree

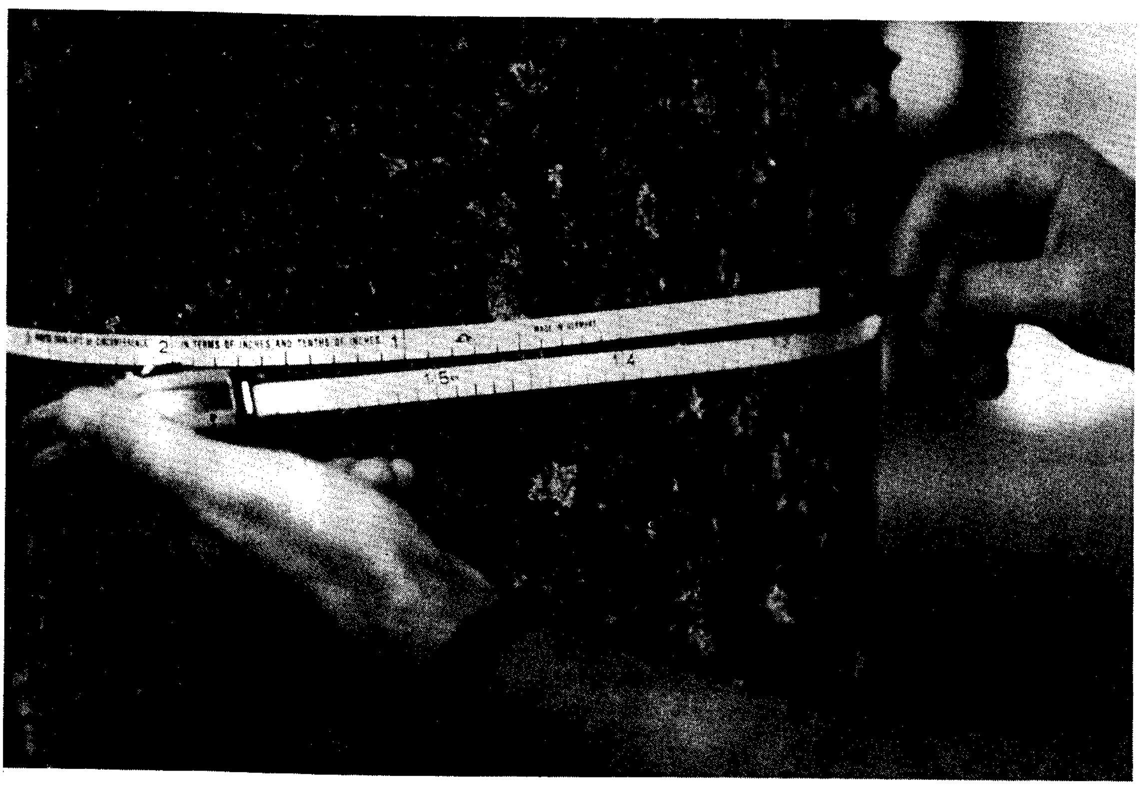

Figure 2. Diameter of this tree is exactly 14 in.

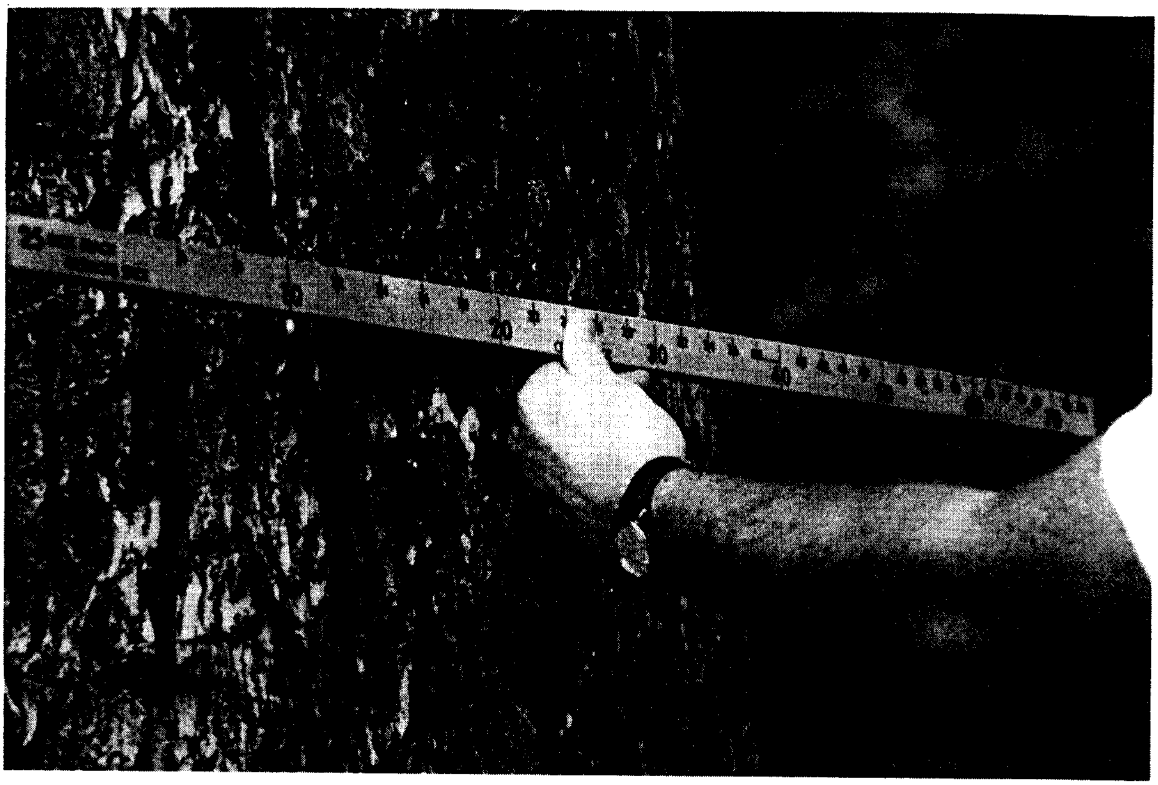

Figure 3. Biltmore stick may be used to measure large stems

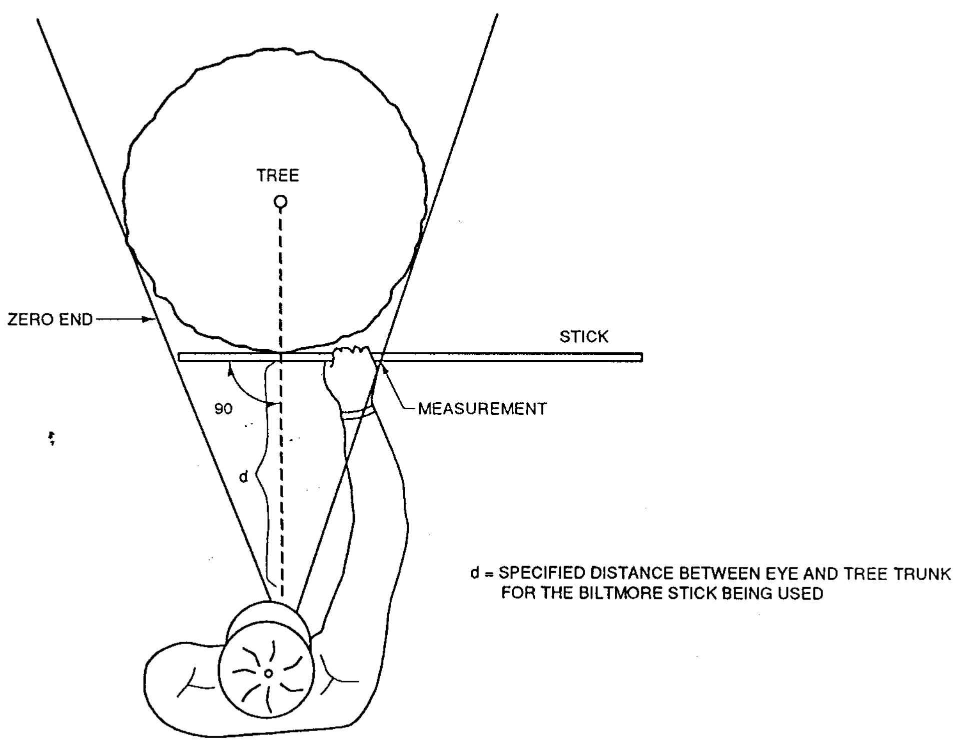

Figure 4. Use of the Biltmore stick to estimate the dbh of a tree (from Hays et al. 1981)

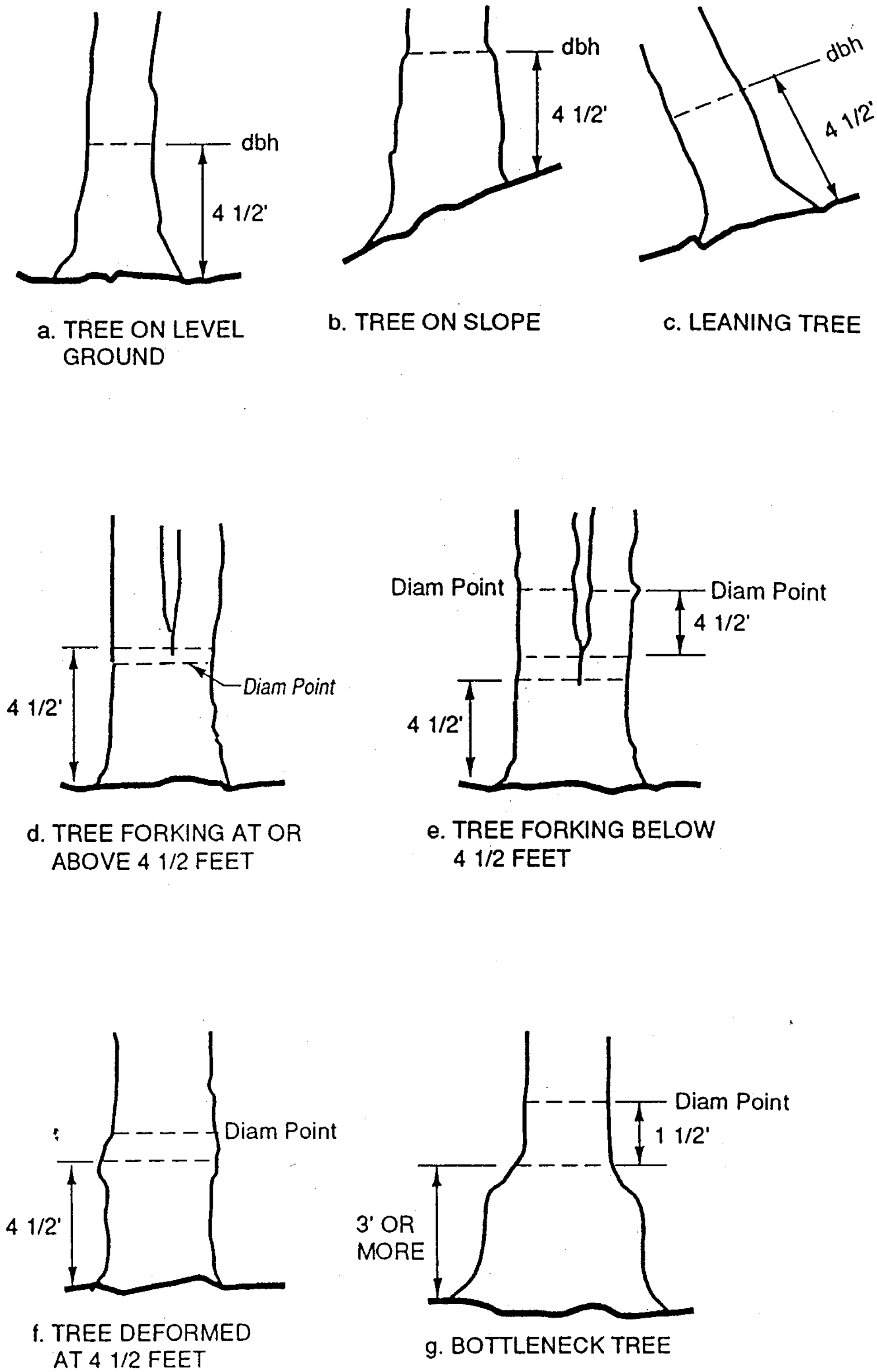

Figure 5. Points of dbh measurement for sloping ground and irregular tree stems (from U.S. Forest Service 1964)

swampy conditions, a 4.5-ft pole may be used to locate true ground level and thus prevent the measurement from being made too high up the stem (Avery 1967). A rational deviation from dbh must be used for trees on sloping ground or for those with irregular stems.

Figures 5b-5g illustrate suggested methods for maintaining consistency in diameter measurements. For trees growing on slopes, dbh should be measured at 4.5 ft above ground on the uphill side of the tree (Fig. 5b). The dbh for a leaning tree is measured at a right angle to an imaginary perpendicular line that is parallel to the side of the tree leaning away from the data collector (Fig. 5c). If a tree forks immediately above dbh, it is measured just below the swell resulting from the double stem (Fig. 5d). Stems that fork below dbh are considered to be separate trees, and diameters are measured approximately 3.5 ft above the fork (Fig. 5e).

When swellings, bumps, depressions, or branches occur at 4.5 ft above ground, diameters are usually taken just above the irregularity at a point where the irregularity ceases to affect normal stem form (Fig. 5f). Trees such as baldcypress (*Taxodium distichum*) and tupelo gum (*Nyssa sylvatica*) are measured 1.5 ft above the pronounced swell or "bottleneck," if the swell is more than 3 ft high (Avery 1967) (Fig. 5g). Such measurements are usually referred to as normal diameters and are abbreviated dn.

PROCEDURE FOR DATA COLLECTION

1. Plot center is marked with a stake wire flag.
2. The recorder remains at plot center. The data collector measures or estimates the dbh of each tree within the plot boundary and calls out the species name and dbh to the recorder.
3. If in doubt about the location of a tree near the boundary, the data collector should pace from plot center to the tree. Data are recorded for every other borderline tree, unless otherwise dictated by the sampling design. (A rope the length of the plot radius may be kept at plot center to rapidly check distances in question.)
4. The Biltmore stick should be used for trees with large diameters or those covered with large vines.
5. When all trees within the plot have been measured and recorded, the field crew moves to the next plot and repeats the procedure.

An outline of the procedure without figures is provided in Appendix A. This single sheet is convenient to carry into the field as a reminder after the technique has been essentially learned.

RECORDING

Blank data forms are provided in Appendix B. The one entitled "Fixed Area Plot: Field Data Sheet" is used for recording field data. The station number is recorded for the first tree measured at each point, and the species name and dbh are recorded for each tree sampled.

Species Names

An abbreviated name or code number is entered for species. Species names may be coded in one of several ways, but the same coding system should be consistently used by all data collectors. Three methods of species name coding are suggested below:

1. Mnemonic system, in which the initial letters of common names identify the species (e.g., SG = sweet gum and SRO = southern red oak in the examples given in this report).

2. Numerical system, in which each species is assigned a number (especially useful for data entered in a field computer).

3. Scientific name abbreviation, a four-letter system in which the first two letters of the generic and specific names are recorded (e.g., PrSe for *Prunus serotina*, the scientific name of black cherry).

Diameter Classes

Diameter may be recorded to the nearest 0.1 in., but it is usually recorded in dbh classes of 1 to 2 in. If 1-in. classes are used, it is customary to record the lower value when diameters fall exactly halfway between inch graduations. For example, the class limits for 8-in. trees are 7.6 in. to 8.5 in.; the 9-in. class ranges from 8.6 to 9.5 in. (Avery 1967). When the 2-in. diameter classes are used, the 8-in. class boundaries commonly range from 7.000 to 8.999+ in.; the 10-in. class spans from 9.000 to 10.999+ in. In the examples provided below, diameters were recorded to the nearest inch, then tallied and analyzed by 2-in. categories.

Example

The first page of field data from an upland hardwood forest stand is presented in Figure 6. The data from Station 1 shows that 7 trees were sampled, and dbh was recorded to the nearest inch. The mnemonic system was used to record species names. The first tree sampled at Station 1 was black gum (*Nyssa sylvatica*) with a diameter of 12 in.

DATA ANALYSIS

Forest stand parameters that can be determined from data collected in the above procedures include the following:

1. Density (numbers per acre).
2. Basal area (square feet of cross-sectional area per acre).
3. Average diameter.

Data analysis forms are provided in Appendix B. On each form, the dbh categories should be entered in the first column on the left, and the tree species names should be entered in the row of blocks under the "Species" heading.

Data Summary

Description. Data from the Field Data Sheet should be summarized on the "Fixed Area Plot: Stand Tally Sheet" in the following manner:

1. Tally the number of trees for each species by dbh class.
2. Count the number of trees of all species in each dbh class and enter the totals in the right-hand column (Total dbh Class).
3. Add the number of trees in the right-hand column (No. 2 above) and enter the total number of trees sampled in the space at the bottom of the column.
4. Count the number of trees of each species in all dbh classes and enter at the bottom of each column. (The total number of trees in this row should equal the total number of trees in the right-hand column.)
5. If more than 1 data sheet is needed, the "Total" blocks may be left blank on all except the last page, or subtotals may be entered and the stand summary presented on the last page.

Example. The data from the upland hardwood stand (Fig. 6) were summarized on the Sample Stand Tally Sheet (Fig. 7) as suggested in the steps above.

FIXED AREA PLOT:FIELD DATA SHEET

AGENCY/OWNER: USACE PROPERTY: Grenada Lake DATE: 6-4-90

COUNTY: Grenada COMPARTMENT/UNIT: 13 ACREAGE:________ PLOT SIZE: 0.1 acre

STAND NUMBER: 28A FOREST TYPE: Upland Hardwood OBSERVER: Mitchell & Hughes

Sta. No.	Sp.	dbh	Sta. No.	Sp.	dbh	Sta. No.	Sp.	dbh
1	BG	12	3 cont.	SG	10	7 cont.	CO	21
	SP	19		SG	8		MH	13
	MH	10		CO	6	8	MH	5
	BG	5	4	CO	6		S	6
	MH	11		PO	19		WHO	18
	BG	6		GA	14	9	WHO	10
	CO	8		WE	6		WHO	9
2	SG	6		PO	7		PO	7
	SG	7		PO	7		WHO	5
	WE	12		PO	10		WHO	5
	W	6	5	WE	13		WHO	5
	BG	6		WHO	5		WHO	5
	SG	6		SRO	13		WHO	10
	BG	11		S	14		WHO	6
	BG	6	6	SG	16		WHO	11
	WHO	7		WHO	11		WHO	9
	BG	11		BG	14	10	WHO	22
	CO	8		MH	5		WHO	22
	SG	6		MH	7		S	17
	S	6		SRO	14		WHO	17
3	WE	12		S	8	11	WE	23
	SP	14	7	MH	9		MH	9
	CO	5		WHO	22		WHO	16
	CO	22		PO	18		WHO	24
	BG	8		WE	7		WHO	8
	BG	8		S	5	12	SG	10
	CO	17		LP	12		SG	15

PAGE 1 OF 2

Figure 6. Sample data sheet to illustrate the recording of data collected in the field

1. The Stand Tally Sheet shows that 8 WHO (white oak, *Quercus alba*) trees in the 6-in. diameter class were sampled in this stand (Fig. 7a).

2. The data in the right-hand column indicate a total of 7 trees in the 16-in. dbh class (Fig. 7b).

3. The summation of numbers in the right-hand column shows that a total of 142 trees were sampled in this upland stand (Fig. 7b).

4. The tally for all dbh classes of each species ("Total" row) shows that 18 SG (sweetgum, *Liquidambar styraciflua*), 12 WE (winged elm, *Ulmus alata*), 12 MH (mockernut hickory, *Carya tomentosa*), and 2 P (persimmon, *Diospyros virginiana*) trees were sampled (Fig. 7).

<u>Density</u>

<u>Description</u>. The steps given below can be used to calculate species and total densities for the dbh classes on the acreage sampled. All density calculations should be entered on the data analysis form entitled "Fixed Area Plot: Density." <u>The numbers of trees used in the calculations are taken from the Stand Tally Sheet</u>.

1. Use the following equation to find the acreage sampled and record at the bottom of the Stand Tally Sheet. Use this acreage for each density calculation.

   Acreage sampled = (Plot size)(Number of plots)

2. Calculate the density, D, of each species by dbh class with the equation

   $$D_{sp\text{-}dbh} = \frac{\text{Number trees sampled}}{\text{Acreage sampled}}$$

3. Add each column to find the total density for each species.

   $$D_{sp\text{-}dbh} = \sum D_{sp} \text{ for all dbh classes}$$

4. Calculate the total density for each dbh class with the equation in step 2 or by adding the densities for all species of that diameter class.

   $$D_{class} = \sum D_{sp\text{-}dbh}$$

5. Find total tree density by using the equation in step 2 or by adding the dbh class densities in the last column.

   $$D_{tree} = \sum D_{class}$$

FIXED AREA PLOT: STAND TALLY SHEET
(Number of trees sampled)

AGENCY/OWNER: USACE PROPERTY: Grenada Lake COUNTY: Grenada DATE: 6-4-90

COMPARTMENT/UNIT: 13 STAND NUMBER: 28A ACREAGE: ____ OBSERVER: Mitchell + Hughes

FOREST TYPE: Upland Hardwood PLOT SIZE: 0.1 acre Page 1 of 2

dbh (In)	Number of Trees by Species							Total dbh Class
	BG	SG	SRO	WHO	WE	CO	PO	
6	卌	卌 ///	////	卌 ///	卌	///		
8	////	///	///	//	//	///	///	
10	/	//		卌 /	//	///	///	
12	////	/	//	/	/	/	/	
14	/	/	////			//		
16		//		/	/	///		
18		/		///		/	/	
20							/	
22			/	卌		//		
24				//	/			
TOTAL	15	18	14	28	12	18	9	

Number of Plots Sampled - 20
Acreage Sampled - (Plot size)(Number plots) - 2 acres

Figure 7. Sample data illustrating the tallying of tree species from the field data sheet shown in Figure 6 (Continued)

FIXED AREA PLOT: STAND TALLY SHEET
(Number of trees sampled)

AGENCY/OWNER: USACE PROPERTY: Grenada Lake COUNTY: Grenada DATE: 6-4-90

COMPARTMENT/UNIT: 13 STAND NUMBER: 28A ACREAGE: ______ OBSERVER: Mitchell & Hughes

FOREST TYPE: Upland Hardwood PLOT SIZE: 0.1acre Page 2 of 2

dbh (In)	Number of Trees by Species								Total dbh Class
	WAO	WTO	MH	GA	SP	LP	YP	P	
6	/	/	///	//				/	41
8			/					/	22
10			///						20
12		/	//		/	/	/		17
14	/		/	/	//	/			14
16									7
18			//						8
20					/				2
22									8
24									3
TOTAL	2	2	12	3	4	2	1	2	142

Number of Plots Sampled = 20
Acreage Sampled = (Plot size)(Number plots) = 2 acres

Figure 7. (Concluded)

Example. The Stand Tally Sheet (Fig. 7) provides numbers of trees used in density calculations, which are entered in the Density table (Fig. 8).

1. Information on the Stand Tally Sheet shows that 20 plots of 0.1 acre were sampled in this stand. Therefore, the total acreage sampled was

   (0.1 acre/plot)(20 plots) = 2 acres

2. The density, $D_{sp\text{-}dbh}$, of each species by dbh class: With the equation in step 2 above, the density of 14-in. SRO (southern red oak, *Quercus falcata*) trees in this sample (Fig. 8a) is calculated to be

$$D_{sp\text{-}dbh} = \frac{4 \text{ trees}}{2 \text{ acres}}$$

$$= 2 \text{ southern red oak trees/acre}$$

3. Individual species densities: In the summation row at the bottom of the table (Fig. 8b), the total density of GA (green ash, *Fraxinus pennsylvanica*) is 1.5 trees/acre.

4. Total density for each dbh class: The data in the last column (Fig. 8b) show that the sum of species densities in the 22-in. class is 4 trees/acre.

5. Total tree density: The summation of dbh class densities (last column) shows a total tree density of 71 trees/acre in the hardwood stand (Fig. 8b). This value equals the summation of individual species densities in the last row.

Basal Area

Description. Basal Area (BA) is determined with the following equation:

$$BA = 0.005454\ d^2$$

where d is the stem diameter.

The constant, 0.005454, converts the diameter to cross-sectional area in square feet. Basal area/acre can be found by following the steps given below. All calculations should be entered on the data analysis form entitled "Fixed Area Plot: Basal Area per Acre." Note: Values for density are taken from the stand density data analysis sheet.

1. The Basal Area Conversion Factor (the basal area of 1 tree of a specified dbh) should be determined first. Find the Basal Area Conversion Factor (**BACF**) for each dbh class by using the class midpoint value for the stem diameter, **d**, in the equation given above. Enter the

FIXED AREA PLOT: DENSITY

AGENCY/OWNER: USACE PROPERTY: Grenada Lake COUNTY: Grenada DATE: 6-4-90

COMPARTMENT/UNIT: 13 STAND NUMBER: 28A ACREAGE: ______ OBSERVER: Mitchell & Hughes

FOREST TYPE: Upland Hardwood PLOT SIZE: 0.1 acre PAGE: 1 OF 2

dbh (In)	Species Density (Trees per Acre)							Density dbh Class
	BG	SG	SRO	WHO	WE	CO	PO	
6	2.5	4.0	2.0	4.0	2.5	1.5		
8	2.0	1.5	1.5	1.0	1.0	1.5	1.5	
10	0.5	1.0		3.0	1.0	1.5	1.5	
12	2.0	0.5	1.0	0.5	0.5	0.5	0.5	
14	0.5	0.5	2.0			1.0		
16		1.0		0.5	0.5	1.5		
18		0.5		1.5		0.5	0.5	
20							0.5	
22			0.5	2.5		1.0		
24				1.0	0.5			
SPECIES DENSITY	7.5	9.0	7.0	14.0	6.0	9.0	4.5	

(No. trees in dbh class from STAND TALLY SHEET)

Species Density (by dbh class) = No. trees in dbh class / Acres Sampled

TOTAL TREE DENSITY (TOTAL NO. TREES/ACREAGE SAMPLED)	

Figure 8. Sample data illustrating the determination of density (Continued)

FIXED AREA PLOT: DENSITY

AGENCY/OWNER: USACE PROPERTY: Grenada Lake COUNTY: Grenada DATE: 6-4-90

COMPARTMENT/UNIT: 13 STAND NUMBER: 28A ACREAGE: ______ OBSERVER: Mitchell & Hughes

FOREST TYPE: Upland Hardwood PLOT SIZE: 0.1 acre PAGE: 2 OF 2

dbh (In)	Species Density (Trees per Acre)								Density dbh Class
	WAO	WIO	MH	GA	SP	LP	YP	P	
6	0.5	0.5	1.5	1.0				0.5	20.5
8			0.5					0.5	11.0
10			1.5						10.0
12		0.5	1.0		0.5	0.5	0.5		8.5
14	0.5		0.5	0.5	1.0	0.5			7.0
16									3.5
18			1.0						4.0
20					0.5				1.0
22									4.0
24									1.5
SPECIES DENSITY	1.0	1.0	6.0	1.5	2.0	1.0	0.5	1.0	

(No. trees in dbh class from STAND TALLY SHEET)

Species Density (by dbh class) = No. trees in dbh class / Acres Sampled

TOTAL TREE DENSITY (TOTAL NO. TREES/ACREAGE SAMPLED)	71

Figure 8. (Concluded)

conversion factor for each dbh class in the second column of the data sheet.

2. Calculate the BA/acre for each species in each dbh class by using the following equation

$$BA_{sp\text{-}dbh}/acre = (BACF_{dbh})(D_{sp\text{-}dbh})$$

3. Find the BA/acre for each dbh class by using the equation

$$BA_{class}/acre = \sum BA_{sp\text{-}dbh}/acre$$

4. Find the BA/acre for each species

$$BA_{sp}/acre = \sum BA_{sp\text{-}dbh}/acre$$

5. Find the total BA/acre

$$\text{Total } BA/acre = \sum BA_{class}$$

or,

$$\text{Total } BA/acre = \sum BA_{sp}$$

Example. Values for density from the stand Density table (Fig. 8) are used to calculate the basal area/acre (Fig. 9).

1. The Basal Area Conversion Factor for each dbh class was found by using the class midpoint value for stem diameter, d, and substituting in the equation

$$BA = 0.005454\ d^2$$

Thus, the Basal Area Conversion Factor (BACF) for trees in the 6-in. dbh class is

$$BACF = 0.005454\ (6)^2$$
$$= 0.1963$$

2. BA/acre for each species in a dbh class: The BA/acre for 12-in. PO (post oak, *Quercus stellata*) trees (Fig. 9a) is

$$BA_{sp\text{-}dbh}/acre = (0.7854)(0.5 \text{ tree/acre})$$
$$= 0.4 \text{ ft}^2$$

3. BA/acre for each dbh class: Data in the last column (Fig. 9b) show that the BA/acre for all 16-in. trees is 4.9 ft^2.

4. Total BA/acre for each species: The last row (Fig. 9b) shows that the BA/acre for WAO (water oak, *Q. nigra*) is 0.6 ft^2.

FIXED AREA PLOT: BASAL AREA PER ACRE

AGENCY/OWNER: USACE PROPERTY: Grenada Lake COUNTY: Grenada DATE: 6-4-90

COMPARTMENT/UNIT: 13 STAND NUMBER: 28A ACREAGE: ____ OBSERVER: Mitchell & Hughes

FOREST TYPE: Upland Hardwood PLOT SIZE: 0.1 acre PAGE 1 OF 2

dbh (In)	Basal Area Conv Factor	Species Basal Area per Acre (B/A Acre)							BA/Acre dbh Class
		BG	SG	SRO	WHO	WE	CO	PO	
6	0.1963	0.5	0.8	0.4	0.8	0.5	0.3		
8	0.3490	0.7	0.5	0.5	0.3	0.1	0.5	0.5	
10	0.5454	0.3	0.5		1.6	0.5	0.8	0.8	
12	0.7854	1.6	0.4	0.8	0.4	0.4	0.4	0.4	
14	1.0690	0.5	0.5	2.1			1.1		
16	1.3962		1.4		0.7	0.7	2.1		
18	1.7671		0.9		2.6		0.9	0.9	
20	2.1816							1.1	
22	2.6397			1.3	6.6		2.6		
24	3.1415				3.1	1.6			
Species BA/Acre		3.6	5.0	5.1	16.1	3.8	8.7	3.7	

BA = $0.005454^2 d$, where d = midpoint of each dbh class
BA Conversion Factor = BA of 1 tree of specified dbh
BA/Acre = BA Conversion Factor x Density (from Density Stand Table)

Total Tree BA/Acre	

Figure 9. Sample data illustrating the determination of basal area/acre (Continued)

FIXED AREA PLOT: BASAL AREA PER ACRE

AGENCY/OWNER: USACE PROPERTY: Grenada Lake COUNTY: DATE: 6-4-90

COMPARTMENT/UNIT: 13 STAND NUMBER: 28A ACREAGE: OBSERVER: Mitchell & Hughes

FOREST TYPE: Upland Hardwood PLOT SIZE: 0.1 acre PAGE 2 OF 2

dbh (In)	Basal Area Conv Factor	Species Basal Area per Acre (B/A Acre)								BA/Acre dbh Class
		WAO	WIO	MH	GA	SP	LP	YP	P	
6	0.1963	0.1	0.1	0.3	0.2				0.1	4.0
8	0.3490			0.2					0.2	3.8
10	0.5454			0.8						5.4
12	0.7854		0.4	0.8		0.4	0.4	0.4		6.7
14	1.0690	0.5		0.5	0.5	1.1	0.5			7.5
16	1.3962									4.9
18	1.7671			1.8		1.1				7.1
20	2.1816									2.2
22	2.6397									10.6
24	3.1415									4.7
Species BA/Acre		0.6	0.5	4.4	0.7	2.6	0.9	0.4	0.3	

Total Tree BA/Acre	56.9

BA = 0.005454^2d, where d = midpoint of each dbh class
BA Conversion Factor = BA of 1 tree of specified dbh
BA/Acre = BA Conversion Factor x Density (from Density Stand Table)

Figure 9. (Concluded)

5. Total BA/acre for area sampled: A summation of BA/acre for all dbh classes (Fig. 9b) gives the total BA/acre for the area sampled, which is 56.9 ft^2.

Average Diameter

Description. The average diameter is calculated from the tree of average basal area by the following procedure.

1. Find the tree of average basal area ($\overline{BA}$) by using the equation

$$\overline{BA} = \frac{\text{Total BA/acre}}{\text{Total density}}$$

$$\overline{BA}_{tree} = \frac{\text{Total BA/acre}}{\text{Number trees/acre}}$$

2. Calculate the dbh of the tree of average basal area with the equation $BA = (0.005454)(d^2)$

where d is the dbh.

therefore,

$$\bar{d} = \sqrt{\frac{\overline{BA}}{0.005454}}$$

Example. Information from the BA/acre table (Fig. 9b) and stand density table (Fig. 8b) is used to calculate the average stand diameter.

1. $\bar{x}$ BA/acre $= \dfrac{56.9 \text{ ft}^2\text{/acre}}{71 \text{ trees/acre}}$

$= 0.8 \text{ ft}^2$

2. Since $BA = 0.005454\ d^2$, then

$$\bar{d} = \sqrt{\frac{0.8}{0.005454}}$$

$$= 12.1 \text{ ft}$$

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APPENDIX A

PROCEDURE FOR DATA COLLECTION

PROCEDURE FOR DATA COLLECTION

1. Plot center is marked with a stake wire flag.
2. The recorder remains at plot center. The data collectors measure or estimate the dbh of each tree within the plot boundary and call out the species name and dbh to the recorder.
3. If in doubt about the location of a tree near the boundary, the collector should pace from plot center to the tree. Data are recorded for <u>every other</u> borderline tree, unless otherwise dictated by the sampling design. (A rope the length of the plot radius may be kept at plot center to rapidly check distances in question.)
4. The Biltmore stick should be used for trees with large diameters or those covered with large vines.
5. When all trees within the plot have been measured and recorded, the field crew moves to the next plot and repeats the procedure.

APPENDIX B

FIXED AREA PLOT DATA FORMS

FIXED AREA PLOT:FIELD DATA SHEET

AGENCY/OWNER:____________________ PROPERTY:_____________________ DATE:__________

COUNTY:____________ COMPARTMENT/UNIT:______ ACREAGE:_________ PLOT SIZE:_____

STAND NUMBER:_____ FOREST TYPE:____________________ OBSERVER:__________________

Sta. No.	Sp.	dbh	Sta. No.	Sp.	dbh	Sta. No.	Sp.	dbh

PAGE ____ OF ____

FIXED AREA PLOT: STAND TALLY SHEET
(Number of trees sampled)

AGENCY/OWNER: ____________ PROPERTY: ____________ COUNTY: ____________ DATE: ________

COMPARTMENT/UNIT: ________ STAND NUMBER: ______ ACREAGE: ______ OBSERVER: ____________

FOREST TYPE: ____________ PLOT SIZE: ______ Page ____ of ____

dbh (In)	Number of Trees by Species							Total dbh Class
TOTAL								

Number of plots sampled = ________
Acreage sampled = (Plot size)(Number plots) = ________

FIXED AREA PLOT: DENSITY

AGENCY/OWNER: ____ PROPERTY: ____ COUNTY: ____ DATE: ____

COMPARTMENT/UNIT: ____ STAND NUMBER: ____ ACREAGE: ____ OBSERVER: ____

FOREST TYPE: ____ PLOT SIZE: ____ PAGE: ____ OF ____

dbh (In)	Species Density (Trees per Acre)							Density dbh Class
SPECIES DENSITY								

(No. trees in dbh class from STAND TALLY SHEET)

$$\text{Species Density (by dbh class)} = \frac{\text{No. trees in dbh class}}{\text{Acres sampled}}$$

TOTAL TREE DENSITY (TOTAL NO. TREES/ACREAGE SAMPLED)	

FIXED AREA PLOT: BASAL AREA PER ACRE

AGENCY/OWNER:______________ PROPERTY:______________ COUNTY:__________ DATE:______

COMPARTMENT/UNIT:__________ STAND NUMBER:______ ACREAGE:______ OBSERVER:______________

FOREST TYPE:______________ PLOT SIZE:______ PAGE ____ OF ____

dbh (In)	Basal Area Conv Factor	Species Basal Area per Acre (B/A Acre)							BA/Acre dbh Class
Species BA/Acre									

Total Tree BA/Acre	

BA = $0.005454d^2$, where d = midpoint of each dbh class
BA Conversion Factor = BA of 1 tree of specified dbh
BA/Acre = BA Conversion Factor × Density (from Density Stand Table)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1995	Final report

4. TITLE AND SUBTITLE
Fixed Area Plot Sampling for Forest Inventory: Section 6.2.4, U.S. Army Corps of Engineers Wildlife Resources Management Manual

5. FUNDING NUMBERS
EIRP WU 32420

6. AUTHOR(S)
Wilma A. Mitchell, H. Glenn Hughes

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199;
Pennsylvania State University-DuBois, DuBois, PA 15801

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report EL-95-27

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers, Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

The fixed area plot technique can be used by biologists and natural resource managers for forest inventory. It is an appropriate method for determining major forest stand parameters such as species composition, density, and basal area. Equipment is inexpensive, and the technique is easy to apply. Topics include guidelines for technique selection and study design, preparations for sampling, and procedures for data collection and analysis. Detailed instructions are given for recording and analyzing data; these are accompanied by numerical examples that illustrate each step of the calculations. Reproducible data forms are provided for project use.

14. SUBJECT TERMS

Fixed area plot	Tree density
Forest inventory	Tree diameter
Tree basal area	Vegetation sampling

15. NUMBER OF PAGES 35

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		